

CLAIMS

What Is Claimed:

1. A tensioner unit, comprising:

a barrel having a bore and an aperture on one end and having a pressurized fluid contained within and forming at least part of a primary accumulator, the primary accumulator having a preset volume of gas V_{g1} at pressure $P1$;

a first piston having a first and second side and slidably carried in the bore of the barrel, the piston having a piston rod that extends from the second side of the piston and through the aperture of the barrel, having one of the sides of the piston in communication with the pressurized fluid, and positioned to increase the pressure $P1$ of the primary accumulator when the piston strokes in the direction of the pressurized fluid;

a secondary accumulator housing having a bore and forming at least part of a secondary accumulator, the secondary accumulator having a preset volume of gas V_{g2} at preselected pressure $P2$;

a fluid separator having first and second sides and positioned between the primary and secondary accumulators to maintain functional separation of fluid volumes of the primary and secondary accumulators when the primary accumulator pressure $P1$ is less than the secondary accumulator pressure $P2$, and to allow functional combining of the fluid volumes of the primary and secondary accumulators when the primary accumulator pressure $P1$ is greater than or equal to the secondary accumulator pressure $P2$;

wherein an effective total gas volume V_{gT} available to the tensioner to maintain tension on a supported riser system substantially equals the primary accumulator gas volume V_{g1} when the primary accumulator pressure $P1$ is less than the secondary accumulator pressure $P2$; and

wherein the effective total gas volume V_{gT} available to the tensioner to maintain tension on the supported system substantially equals the sum of the primary accumulator gas volume V_{g1} plus the secondary accumulator gas volume V_{g2} when the pressure $P1$ is greater than or equal to the secondary accumulator pressure $P2$.

2. The tensioner unit of claim 1, further comprising a tubular housing surrounding the barrel and having pressurized fluid contained within and forming a part of the primary accumulator, and wherein:

the piston rod includes a bore which forms the secondary accumulator housing;

the barrel has a port on one end in fluid communication with the tubular housing;

the first piston has an opening in fluid communication with the port;

the bore of the piston rod is in fluid communication with the opening in the piston;

the fluid separator comprises a second piston having first and second sides and sealingly and slidably carried in the bore of the piston rod;

the bore of the barrel, the bore of the tubular housing, and the first sides of the first and second piston define the primary accumulator; and

the bore of the piston rod and the second side of the second piston define the secondary accumulator.

3. The tensioner unit of claim 1, wherein:

the first piston has an opening in fluid communication with the barrel;

the piston rod includes a bore in fluid communication with the opening in the piston;

the secondary accumulator housing is separate from the barrel and is in fluid communication with the second side of the fluid separator; and

the first side of the fluid separator is in fluid communication with an opening in one of the bore of the piston rod and the bore of the barrel.

4. The tensioner unit of claim 3, wherein:

the bore of the barrel, the bore of the piston rod, the bore of the secondary accumulator housing, the first side of the first piston, and first side of the fluid separator define the primary accumulator;

the bore of the secondary accumulator housing and a second side of the fluid separator define the secondary accumulator;

the fluid separator comprises a second piston sealingly and slidably carried in the bore of the secondary accumulator housing; and

the bore of the secondary accumulator housing further includes an extension stop spaced from an end of the secondary accumulator housing which limits maximum travel of the second piston during piston rod extension corresponding to a decrease in primary accumulator pressure P1 below that of the secondary accumulator pressure P2.

5. The tensioner unit of claim 3, wherein:

the bore of the barrel, the bore of the piston rod, the bore of the secondary accumulator housing, the first side of the first piston, and first side of the fluid separator define the primary accumulator;

the bore of the secondary accumulator housing and a second side of the fluid separator define the secondary accumulator; and

the fluid separator comprises a bladder sealingly engaged in a fixed position within the bore of the secondary accumulator housing.

6. The tensioner unit of claim 3, wherein:

the fluid separator comprises a valve having a first fluid connection assembly in fluid communication with the pressurized fluid in one of the bore of the piston rod and the bore of the barrel, and a second fluid connection assembly in fluid communication with the pressurized fluid in the bore of the secondary accumulator housing;

the bore of the barrel, the bore of the piston rod, the first side of the first piston, and the first fluid connection assembly of the valve define the primary accumulator;

the bore of the tubular housing and the second fluid connection assembly of the valve define a secondary accumulator; and wherein

the valve connects the pressurized fluid in the bore of the barrel with the pressurized fluid in the bore of the secondary accumulator housing when the pressure P1 in the primary accumulator exceeds the preselected pressure P2 of the secondary accumulator.

7. The tensioner unit of claim 1, further comprising a tubular housing surrounding the barrel, the tubular housing having a bore, a fluid communication opening, and pressurized fluid contained within, and forming a part of the primary accumulator, and wherein:

the secondary accumulator housing is separate from both the barrel and the tubular housing and is in fluid communication with the second side of the fluid separator;

the first side of the fluid separator is in fluid communication with the tubular housing through the fluid communication opening; and

the first side of the first piston forms a fluid barrier.

8. The tensioner unit of claim 7, wherein:

the bore of the barrel, the bore of the tubular housing, the bore of the secondary accumulator housing, the first side of the first piston, and first side of the fluid separator define the primary accumulator;

the bore of the secondary accumulator housing and a second side of the fluid separator define the secondary accumulator;

the fluid separator comprises a second piston sealingly and slidably carried in the bore of the secondary accumulator housing; and

the bore of the secondary accumulator housing further includes an extension stop spaced from an end of the secondary accumulator housing which limits maximum travel of the second piston during piston rod extension corresponding to a decrease in primary accumulator pressure P1 below that of the secondary accumulator pressure P2.

9. The tensioner unit of claim 7, wherein:

the bore of the barrel, the bore of the piston rod, the first side of the first piston, the bore of the secondary accumulator housing, and first side of the fluid separator define the primary accumulator;

the bore of the secondary accumulator housing and a second side of the fluid separator define the secondary accumulator; and

the fluid separator comprises a bladder sealingly engaged in a fixed position within the bore of the secondary accumulator housing.

10. The tensioner unit of claim 7, wherein:

the fluid separator comprises a valve having a first fluid connection assembly in fluid communication with the pressurized fluid in the bore of the tubular housing, and a second fluid connection assembly in fluid communication with the pressurized fluid in the bore of the secondary accumulator housing;

the bore of the barrel, the first side of the first piston, the bore of the tubular housing, and the first fluid connection assembly of the valve define the primary accumulator;

the bore of the secondary accumulator housing and the second fluid connection assembly of the valve define the secondary accumulator; and wherein

the valve connects the pressurized fluid in the bore of the tubular housing with pressurized fluid in the bore of the secondary accumulator housing when the pressure P1 in the primary accumulator exceeds the preselected pressure P2 of the secondary accumulator.

11. The tensioner unit of claim 1, further comprising a primary accumulator housing having a bore, a plurality of fluid communication apertures, and having pressurized fluid contained within and forming a part of the primary accumulator, and wherein:

the first side of the first piston forms a fluid barrier;

the primary accumulator housing is separate from the barrel and is in fluid communication with the barrel and the first side of the fluid separator through the fluid communication apertures;

the secondary accumulator housing is separate from the barrel and the primary accumulator housing and is in fluid communication with the second side of the fluid separator; and

the first side of the fluid separator is in fluid communication with the bore of the primary accumulator housing and bore of the barrel through the fluid communication apertures.

12. The tensioner unit of claim 11, wherein:

the bore of the barrel, the first side of the first piston, the bore of the primary accumulator housing, the bore of the secondary accumulator housing, and the first side of the fluid separator define the primary accumulator;

the bore of the secondary accumulator housing and the second side of the fluid separator define the secondary accumulator;

the fluid separator comprises a second piston sealingly and slidably carried in the bore of the secondary accumulator housing; and

the bore of the secondary accumulator housing further includes an extension stop spaced from an end of the secondary accumulator housing which limits maximum travel of the second piston during piston rod extension corresponding to a decrease in primary accumulator pressure P1 below that of the secondary accumulator pressure P2.

13. The tensioner unit of claim 11, wherein:

the bore of the barrel, the first side of the first piston, the bore of the primary accumulator housing, the bore of the secondary accumulator housing, and the first side of the fluid separator define the primary accumulator;

the bore of the secondary accumulator housing and the second side of the fluid separator define the secondary accumulator; and

the fluid separator comprises a bladder sealingly engaged in a fixed position within the bore of the secondary accumulator housing.

14. The tensioner unit of claim 11, wherein:

the fluid separator comprises a valve having a first fluid connection assembly in fluid communication with the pressurized fluid in the bore of the primary accumulator housing which is in communication with the bore of the barrel, and a second fluid connection assembly in fluid communication with the pressurized fluid in the bore of the secondary accumulator housing;

the bore of the barrel, the first side of the first piston, the bore of the primary accumulator housing, and the first fluid connection assembly of the valve arrangement define the primary accumulator;

the bore of the secondary accumulator housing and the second side of the fluid separator define the secondary accumulator; and

the valve connects the pressurized fluid in the bore of the primary accumulator housing and the bore of the barrel with the pressurized fluid in the bore of the secondary accumulator housing when the pressure P_1 in the primary accumulator exceeds the preselected pressure P_2 of the secondary accumulator.

15. A riser tensioning system having a riser extending between subsea well equipment and a floating vessel having an operational platform engaged with the riser, a tensioner unit comprising:

- a barrel having a port on one end;
- a first piston slidably carried in the barrel and having an opening in fluid communication with the port;
- a piston rod extending from the barrel and having a bore in fluid communication with the opening in the piston;
- a second piston sealingly and slidably carried in the bore of the piston rod;
- a primary accumulator in fluid communication with the port and having pressurized fluid therein that communicates with first sides of the first and second piston;
- and wherein:
 - the bore of the piston rod and a second side of the second piston define a secondary accumulator containing a pressurized fluid;
 - the tensioner unit is positioned between the riser and the platform;
 - a first section of the tensioner unit is connected to the riser; and
 - a second section of the tensioner unit is connected to the platform.

16. The tensioning system of claim 15, wherein the bore of the piston rod of the tensioner unit includes an extension stop which limits maximum travel of the second piston during piston rod extension.

17. The tensioning system of claim 15, wherein the bore of the piston rod of the tensioner unit includes a retraction stop spaced from an end of the piston rod which limits maximum travel of the second piston during piston rod retraction.

18. The tensioning system of claim 15, wherein the primary accumulator of the tensioner unit comprises a tubular housing surrounding the barrel.

19. The tensioning system of claim 15, wherein the tensioner unit further comprises a barrel extension extending from the barrel which provides for fluid communication between the barrel port and the primary accumulator.

20. A tensioner unit, comprising:

- a barrel including a bore;

- a first piston slidably carried in the bore of the barrel and having an opening in fluid communication with a pressurized fluid;

- a piston rod extending from the barrel and having a bore in fluid communication with the opening in the piston;

- a secondary accumulator housing having a bore;

- a fluid separator sealingly engaging the bore of the secondary accumulator housing and having a first and a second side to separate a plurality of volumes of fluid;

- a primary accumulator in fluid communication with the bore of the secondary accumulator housing through an opening in at least one of the piston rod and barrel and having pressurized fluid therein that communicates with the first side of the first piston and first side of the fluid separator; and

- the bore of the secondary accumulator housing and a second side of the fluid separator defining a secondary accumulator containing a pressurized fluid within.

21. The tensioner unit of claim 20, wherein the fluid separator comprises a second piston sealingly and slidably carried in the bore of the secondary accumulator housing.

22. The tensioner unit of claim 21, wherein the bore of the secondary accumulator housing further includes an extension stop spaced from an end of the secondary accumulator housing which limits maximum travel of the second piston during piston rod extension corresponding to a decrease in primary accumulator pressure below that of the secondary accumulator pressure.

23. The tensioner unit of claim 20, wherein the fluid separator comprises a bladder sealingly engaged in a fixed position within the bore of the secondary accumulator housing.

24. A tensioner unit, comprising:

a barrel having a port on one end and in communication with a pressurized fluid;

a tubular housing surrounding the barrel and having a bore, an opening, and an aperture on one end;

a piston having a first and second side, slidably carried in the bore of the barrel, and having a piston rod extending from the barrel on the second side of the piston through the aperture;

a secondary accumulator housing including a bore, an opening in the bore in fluid communication with the opening in the bore of the tubular housing, and a fluid separator sealingly engaging the bore of the secondary accumulator housing and having a first and a second side to separate a plurality of volumes of fluid;

a primary accumulator in fluid communication with the port of the barrel and the opening in the bore of the tubular housing, and having pressurized fluid therein that communicates with the first side of the piston and the first side of the fluid separator; and

the bore of the secondary accumulator housing and the second side of the fluid separator defining a secondary accumulator containing a pressurized fluid.

25. The tensioner unit of claim 24, wherein the fluid separator comprises a second piston sealingly and slidably carried in the bore of the secondary accumulator housing.

26. The tensioner unit of claim 25, wherein the bore of the secondary accumulator housing further includes an extension stop spaced from an end of the secondary accumulator housing which limits maximum travel of the second piston during piston rod

extension corresponding to a decrease in primary accumulator pressure below that of the secondary accumulator pressure.

27. The tensioner unit of claim 24, wherein the fluid separator comprises a bladder sealingly engaged in a fixed position within the bore of the secondary accumulator housing.

28. A tensioner unit, comprising:

- a barrel having a bore, a fluid communication opening, an aperture on one end, and having a volume of pressurized fluid therein;

- a first piston having a first and a second side, slidingly carried in the bore of the barrel and having a piston rod that extends from the piston through the fluid communication opening of the barrel;

- a primary accumulator housing having a bore, a plurality of fluid communication openings, and in fluid communication with the fluid communication opening of the barrel;

- a secondary accumulator housing having a bore, a fluid communication opening, and having a fluid separator sealingly engaging the bore of the secondary accumulator housing, the fluid separator having a first and a second side to separate fluid in the secondary accumulator housing, the secondary accumulator housing further being in fluid communication with the primary accumulator housing through the fluid communication opening of the secondary accumulator housing and one of the fluid communication openings of the primary accumulator housing;

- a primary accumulator in fluid communication with the fluid communication opening of the barrel and the fluid communication opening of the secondary accumulator housing and having pressurized fluid that communicates with the first side of the first piston and first side of the fluid separator; and

- the bore of the secondary accumulator housing and the second side of the fluid separator defining a secondary accumulator containing a pressurized fluid.

29. The tensioner unit of claim 28, wherein the fluid separator comprises a second piston sealingly and slidably carried in the bore of the secondary accumulator housing.

30. The tensioner unit of claim 29, wherein the bore of the secondary accumulator housing further includes a lower stop spaced from an end of the secondary accumulator housing which limits maximum travel of the second piston during piston rod extension corresponding to a decrease in pressure of the primary accumulator below the pressure of the secondary accumulator.

31. The tensioner unit of claim 29, wherein the fluid separator comprises a bladder sealingly engaged in a fixed position within the bore of the secondary accumulator housing.

32. A tensioner unit, comprising:

- a barrel including a bore and an aperture on one end and having a pressurized fluid contained within and forming at least part of a primary accumulator;

- a piston in communication with a pressurized fluid and slidably carried in the bore of the barrel and having a piston rod that extends from the piston through the aperture;

- a secondary accumulator housing having a bore and a pressurized fluid having a preselected pressure contained within;

- a valve arrangement having a first fluid connection assembly in fluid communication with the pressurized fluid in one of the bore of the piston rod and the bore of the barrel, and a second fluid connection assembly in fluid communication with the pressurized fluid in the bore of the secondary accumulator housing to connect the pressurized fluid in the bore of the barrel with the pressurized fluid in the bore of the secondary accumulator housing when the pressure of the pressurized fluid in the bore of the barrel exceeds the preselected pressure of the pressurized fluid in the bore of the secondary accumulator housing;

the bore of the barrel, and the first fluid connection assembly of the valve arrangement defining a primary accumulator; and

the bore of the secondary accumulator housing and the second fluid connection assembly of the valve arrangement defining a secondary accumulator.

33. A method of maintaining a selected range of tension on a riser extending between subsea well equipment and a floating vessel, comprising the steps of:

providing a barrel having a bore and an aperture on one end, the barrel forming at least part of a primary accumulator;

mounting a piston slidably in the barrel, the piston having a piston rod extending from the barrel through the aperture;

providing a secondary accumulator housing having a bore and forming at least part of a secondary accumulator;

mounting a fluid separator between the primary and secondary accumulators;

connecting either the piston rod or the barrel to the vessel and the other to the riser;

applying fluid pressure from the primary accumulator to a first side of the first piston and a first side of the fluid separator;

applying fluid pressure into the secondary accumulator housing on a second side of the fluid separator until pressure on both sides of the fluid separator equal;

applying tension to the riser by the force due to pressure of fluid in the primary accumulator, urging the piston rod to extend;

if vessel moves closer to the subsea equipment, allowing the piston rod to extend farther and allowing the fluid separator to functionally isolate the fluid volume in the secondary accumulator from the fluid volume in the primary accumulator to maintain tension range; and

if vessel moves farther from the subsea equipment, allowing the piston rod to retract and allowing the fluid separator to functionally combine the fluid volume in the secondary accumulator with the fluid volume in the primary accumulator to maintain tension range.

34. The method of claim 33, further comprising limiting maximum travel of the second piston during piston rod extension by contacting the second piston with an extension stop.

35. The method of claim 33, further comprising limiting maximum travel of the second piston during piston rod retraction by contacting the second piston with a retraction stop.